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No. 736,288



June 14, 1966 ISSUED CLASS

166-16

CLASSIFICATION

GROUP

CANADIAN PATENT

LINER EXPANDER

Joe C. Stall, Tulsa, Oklahoma, U.S.A.

Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

APPLICATION No. 897, 460

PRIORITY DATE

No. OF CLAIMS

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing ; or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the vall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be vrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the losding on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lover shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

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- 6 -

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft lo.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein P_{c} is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve QA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in vell casing, the made-up tool is lowered into the vell as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1 1. A device for expanding a metallic liner inside a conduit which 2 device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft 5 6 between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft 7 8 to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against 9 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 3 conduit to expand said liner: a cylindrical shaft element, an expanding die member attached to said shaft, said die member comprising a plurality of arm 5 members disposed around said shaft and being pivotable outwardly therefrom to 6 contact said liner, a cone member slidably positioned on said shaft between 7 said shaft and said arm members to urge said arm members outwardly from said 8 shaft, and a constant force spring member positioned on said shaft to contact 9 said cone member and to maintain said cone member in contact with said arm 10 members, whereby said arm members are urged outwardly by a substantially 11 constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

 sleeve-like element connected to said movable bearing plate member and

 slidably positioned on said shaft and a member connected to said shaft to

 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the didnet face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable out-5 wardly therefrom to contact the liner; a conical expanding member slidably 6 positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each 7 8 having a long rectangular cross-section and disposed circumferentially about 9 said shaft; an upper bearing plate member and a lower bearing plate member, 10 each slidably positioned on said shaft and contacting opposite ends of said 11 columns; limiting sleeves attached to each of said bearing plate members and slidably positioned on said shaft; a shoulder member on said shaft; a 12 13 differential screw element connecting said shoulder and said shaft to apply 14 a buckling load to said columns; said shoulder being engageable with the 15 limiting sleeve connected to said lower bearing plate member, whereby the 16 axial travel of said bearing plate members is limited; said column members 17 transmitting their buckling load to said arm members to urge said arm members 18 outwardly with a substantially constant force.

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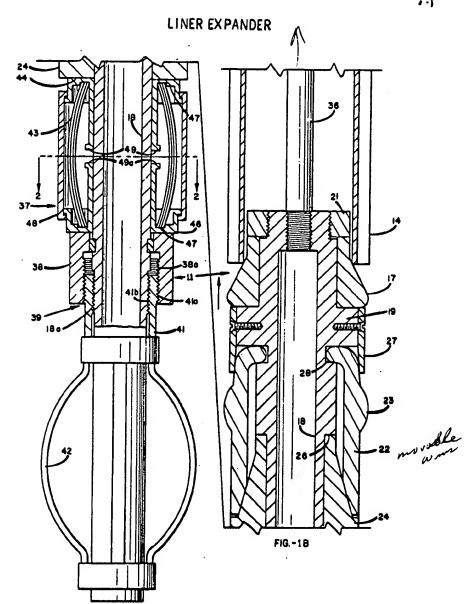
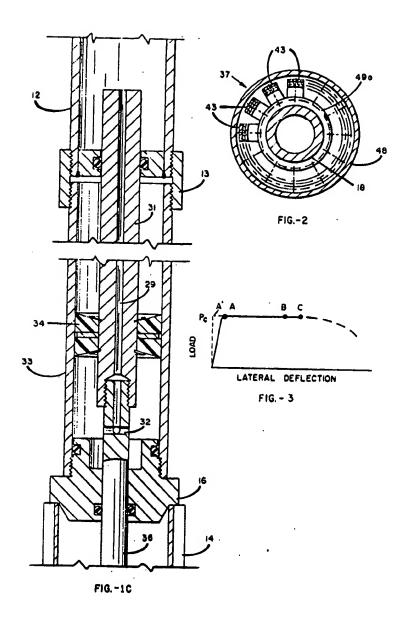


FIG.-1A



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2. A dorice for expending a metallic liner inside a conduct which device comprises a shaft almost, on asympting the number observed as mid-start olcones, stid die number comprising a movable liner-forming member positionel on said shaft and being cottably noveble in respect thereof to contact mid liner, as expender mowher skidably positioned on said shaft between said shaft each said die number to move said liner-forming member from said shaft, and a constant force spring number positioned on said shaft to contact said styrater symbor and to maintain said expenses member against said liner-forming senter, whereby said liner-forming senter is several starts.

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3. The ferrios of Claim 2 shareds said scentars force speing nester comprises a planality of estimate fixposed around said shaft, a fixet bearing plate member and a second bearing plate nester, each of said bearing plate members conducting opposite onle of said columns, at least one of said tearing plate members being movehly positioned on said shaft and being in constant with said come member, stop means commerced to said start to limit the axial traval of said movehly bearing plate number along said shaft, and compression means for maintaining a lateral defication in said columns.

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- . A. The device of Claim 3 wherein ends compression grows comprises a $4100\,\mathrm{mm/s}$ a grew consecutor main agrang number and smill shaft.
- 5. The device of Chain 3 wherein anid shop means comprises a above-like element commerced to said southle hearing plate seabur and michally positioned on said short and a souther communication and sharft to limit the return of said above-like element.
- 6. The device of their 3 whereis said columns have a machingular pross-station, the width being greater than the Mickey, and bearing the wider flow moral to the dismotor of said shaft.
- 7. A device for installing on expected estallis lists to a contact class a extinction sheft oliment; on expending the number manded on mid shall, said the member suspensions a planning of are southern disposed chreshally arouse the outside of said shaft and being ploutable outmaily therefrom to equiport the liner; a scaled anymhing maker slidebly him agus or stratum was birm had that hime counted thate him so be re cetamoniy from said shaft; a planelity of almost columns, each baving a long rectangular occas-section and disposed streambinechially should said chait; an upper bearing plate sember and a lower tearing plate stater, such slikely positioned on said mast and contacting opposite ands of said liniting alseres uttended to each of said bearing plate numbers and alidably positioned on said statts a shoulder smaker on said shafts a differential acres played summeting will shoulder and said state to apply a lanking lead to said enisones suid thouless being emphasize with the limiting siners semmerted to said lower bearing plate memory, whereby the ariel treval of mais bearing plate numbers is limited; mil column ventors transmitting their bushing losd to exid are numbers to urgs said are greaters esterrilly with a substantially comptant force.

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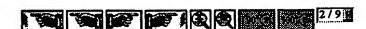
fince tools of the type manifored above of the are employed in welldeep in the growd, it is highly preferable that a tool be used which under no circumstances will become stack in the well or same damage to the well. Any such trouble cocurring in a well see records in considerable tops in time and creat consess in making regains.

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My investion will be before understood by reference to the following description and the ecompanying drawings wherein:

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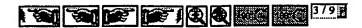
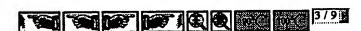


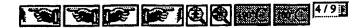
Figure 2 to a sectional when of the apparatus of Figure 1A tabus at line 2-2; and

Figure 5 is a typical plot of applied lost versus definition for the constant force spring device of the invention.

Inferring to the Averings, Pipers 1A is the bottom portion of a liner expending tool for one in installing a metallic liner in a well, while Figure 19 illustrates the stable section of such a tool and Figure 10 topessents the upper sertion of the teal. The expending took il is attached to standard well folding lif by accepting 15 ond, topically, may to lowered from the surross through a well ensing (not shown) to a point in the source at which it is sectred to invisit a metallic liner. Before inserting the test into the well, an elemented vertically correspond timer th fabricated from mild stood, or ether suitable miliable meterial, is placed on the tool. The correspond liner is eccured in position by contact at its upper end with a cylindrical shoulder medier 16 and, at the lover end by content with a first-stage espanding die 17 in the form of a troposted circular core stick serves as a firststage expending die in the sevent baretrafter described. The expending die is fixedly ablached to a controlly located, elemented cylindrical bollow short ld which forms a portion of the body of the tool. As shown, the expending size 17 is held in place between a lower shoulder 19 and collar 21 threaded outs the short. A plurality or morphic eros 25, precently provided with outserelly calarges portions 25 sear the top; are disposed in the form of a equinter of shaft 18. The enlarged portions of the eras 23 upon being moved outvarily ecrised the liner to perfore the final step of expenting the sucregated. .. liner into a entertactively epitatrical shape. The are members IN two pivotally of to the staff so as to be movehic outwardly from the shaff by a tapared expending number 26 alidably positioned on the sheft to serve as a second-stage appender. The sortees of the member 20, as shown, sower specially along the start to sagage with the eras and more than outvertly. Advantageously, the closes of the same 22 and the outside earlies of expending member 25 fore enting sestions, typically categoral in chaps. The expension of the era



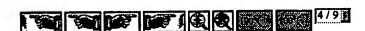
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wrill it contains shoulder to provided on two staft. As number th moves in a documently direction error for fall impurity towers the elect. The expending arms 22 are built to place on the shaft by collect 27 and circular proves 20 provided on the shaft.

The expending tool, comprising the first-stage die end the secondstage die is dress through the limit to expend to us piece in the contage. Due first-stage die provides a grots disformation of the limit so that it is expended outworthy against the well of the sening. The second-stage die then passes through the limit and performs the final expendent to smooth the inner section of the limit and to provide more even contact between the limit and the well of the coming and effort a finid-light seal.

In operation, the liner setting tool is assembled at the surface, so described shore, and a glass thoth saturated with a restause material may be unapped around the corrugated tobe to form the liner. The assembly is lowered into the wall at the leastion at which the liner is to be set. A siquid, such so oil, is then people under presence down the well tubing sed flows through the parcegnary 29 provided to golished not 31, through purts 52 and into syllader 35 consected to the upper soil of the shoulder 16. Upon the application of fluid printers to the oplinder, the piston 34 second to polished soi 51 moves upwortly in sylinder 35. As shows, rod 36 commerce polished rod 31 and shaft 15 spot which is measure the First-riege expanding size 17. Then the piston % neves upwertly through the splinter 35 the expending die 17 and the secondstage die 22 ero drove upwerdly into the corrupted liner ih and "iron out" the corrections is the liner, so that the expected liner may contect the tunide wall of the cesting in which it is being installed. Positioned to the shall below the expending neater th is a comment tures syring number 37 which is employed to trips the expending number against the exploiting same 22 with a entraturately constant force. The force exerted against the and sembles being exhetentially constant, the force transmitted through the arm as liner and to the suring will be substantially constant so that either sticking of the tool in the centag or recture of the carded to precluded. Of course, the three provides by the opring member is preselected so that the frictional



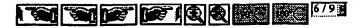
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forces between the tool and the liner and the presence emerted definet the one ing are emirculated at predaturations eafs levels. The constant force spring maker assures that the contact presence between the liner founds purious 23 of the sous 22 is great cough to provide the Sovices deformation of the sea-

The equators force spring season 77 is alignity mounted on the shart 135 and half between the expension alongst 256 and a splinarization lower shealder master 35 forwing a portion of a disfluential server alongst 39 which transmits the localing on opring number 77 to shart master 15. The diffragation server alongst comprises that weather 15 as the certain of which are one as a transmit along the lower master 35 provided with female threads 55s and threads 15s, the lower master 35 provided with female threads 55s and threads seater 51 provided with threads 51s and threads seater 51 provided with threads 51s and threads seater 51 provided with threads on the shart and the sheatler. But two sets of threads are contras, such as square, andiffed square, or fame threads, to rithertand very high loads and differ in pitch so that smoother 35 is sound specify on the shart 15 when the shart is revolved relative to thinkle \$1. The shoulder 36 is secured to the shart 15 by splines 55 so that 11 can slide longitudinally, but it is not free to rotate on the shart. Finally areached to the lower set of the thinkle is a friction scalar, such as but springs \$2, a hydralically estuated friction pas, or other such device for frictionally secured part the friends with respect to the shart. Producably, the direction of the chantles to start threads 15s, e.g. right-head threads 35s, with the pitch, or land, or threads 15s is slightly greater than the start approximately 1.7-lands outside discover and five and threads are a shart approximately 1.7-lands outside discover and five and threads weather threads 15s of sharts approximately 1.7-lands outside discover and five and threads weather threads 15s of sharts approximately 1.7-lands outside discover and five and threads weather threads 15s of sharts approximately 1.7-lands outside discover and five and threads.



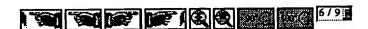


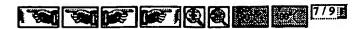
Constant force spring element 37 comprises solven element \$3, element tageonally servicing or a plurality of alongsted solumes disposed around shelfs 15. Byper bearing place number \$4 is in contact with the diper ands of the solume end to elifably positioned on shart 15 to trements the force of the ageing longitudinally against the bottom and of expenden seabor \$4. Lower hearing place number \$6 contacts the lover main of the column and 10 moved specially along the saufit by large bearing movement of lover shoulder \$9 on a result of revolving differential surver almost \$9. Greaves \$7 are provided in such of the bearing places, to force as upper race and a lover race, into which the each of the column are inserted. These grooves my in chapet to section with the shape of the column onto if desired. A cover \$8 any be employed to ambine foreign matter from the spring mechanism sank to protect the cortex.

A necess for limiting the deflection of the columns to required.

Although the column element furctions in a builded nondition, application of crossedies acquires itself therefore would neces total failure or repters of the columns. Therefore, a pair of stope by each by one has are provided for this purpose. In shore, the stope are rigidly communied to the burring plates, and, in affort comprise upper and linear limiting alasman positioned on the shaft to alide longitudinally thereon. The units of the stope may some toward, or may from, each other so the load in the cycle almost vertex. Lover slaves by its prevented from reading dama by laster shoulder 36 normanted to the chart 18. However, the specing between the made in much as to limit the longitudinal traval of the notion plant numbers as may move together to prevent permanent deformation of the column almosts 53. Turious alternative mans for preventing seases to the solumn almosts 53. Turious alternative mans for preventing accepted on the chart may serve as anope, or the cover 48 provides of the suitable connections may be suplayed for this purpose to limit longitudinal and/or lateral aerhearties of columns.

The columns of the calman element h) may be arranged around the chart ld, which as shown here turns a portion of the body of the spring derive, with make of the columns fithed in the recen by. The solumns may be

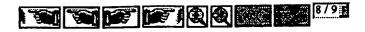




ritted closely together as abore, or say he spaced around the race, with represented used between them to maintain the desired spacing. The rembet of solution employed will depute upon colours themselectrical and the emission of construction. For example, the elementary ratio of the column may be excisely, end the column may see record, flat, fixed or hanged. The performed construction is a thin, element column with mondes ands, from to now within the races shaped to the convenient of the solution code. Materials which may be estimferiorily employed for the solution are code. Materials which may be called referring and minimal-elements stabless stop or them and loss alloy steads, chronium and minimal-elements stabless stops, we know and loss alloys and other similar materials providing actisfectory symbosismi properties. Typically, the individual column are of long restamplies cross-costion, with the sidth bring positor than the latchess, and arranged so that the wider race of the notures is assent to the climater of the abort. Thus, with surfacient consecution losing, the colleges backle, and tend shout the minimal having the loss's consect of inertia, e.g., outwardly surp frue the abort 15.

For example, a group of columns U.167-inch thick by 0.838-inch wide by 10.626-inches long, with the ands rounded, were fabricated from A.1.8.I high orders, question and Arman at 775°F. Bush column was found to require a critical suspensation leading of 550 pounds in order to bushle the address. After bushling, the animan were found to have a very flat spring characteristic, as shows in Figure 3, whereis P₀ is the critical bushling load and point 0 represents the load and deflection at which the stress in the extense filters of the delives exceed the yield point of the untertal. Shearesteelly, the chape of this spring characteristic curve is described by serve 04'AlO. Actually, Only curve is described by GAIO due to friction in the system. Potote A and 3 represent typical vertical limits, which, at course, may be varied according to the application for which the spring is designed. For excepts, where a large master of floring cycles are not subdictated, a working stress just below the yield point may be used, while with a great number of florines, the working stress may be hald to less than the endurance limit of the meterial of construction. In the above-maritional basis, the latersh deflection was limited to

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approximately one inch, at which the longitudinal deflortion was approximately 0.825 inches. From more defination to the assisten deflortion, the \$50-pound loading was fromt to be substantially constant.

In emother test a spring device was built, as shown, employing 80 columns, each having a critical bushling load of 1250 posses. The internal declaration was limited between 0 and about 3.00 inches by empropriately positioning the stope. Once compressional loading, the spring element bushlest wit other translating 25,000 posses and from a long-tudient defication of 0.0% inside (making) to stook 0.15 inches the load reasonal substantially at 85,000

Of source, in conjustes a spring element on above it in advantagements of the greatest possible value of longitudinal defluction for specified values of laboral deflection and critical bushing load, while unintelling the attest level in the columns at a cafe level. The greatered columns, therefore, are landscoped, as shown in Pigartes 18 and 2, with exitiple flat employs unline to seals column.

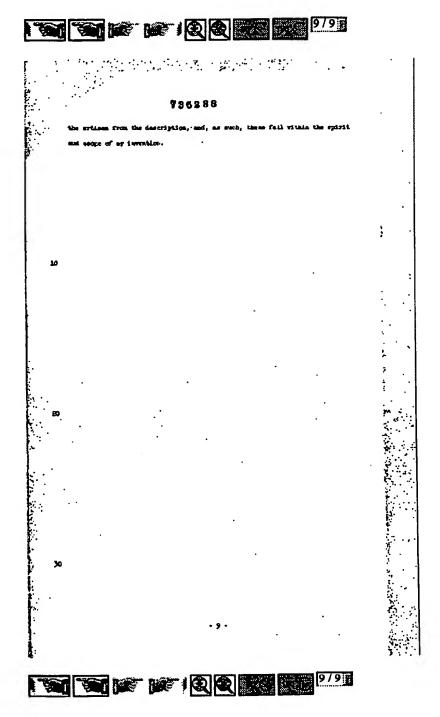
In the operation of the above expecting tool for switing a liner in well ending, the ands-up tool is lowered into the well as mentioned above, with the area 22 in the retreated position. Shen the tool is at the desired level, the sain totaling is revealed. The fristion number by require with the wall of the enting and prevents thinkle 41 from revolving. With several revolutions of the twing, lower absolute 35 is moved agreeming by differential server 39 to bushing pring almost 37 which has a predeferminal critical bushing load. Shis land is transmitted agreedly agricult the lower and of argument 26, and its theorem surface is engaged with the taperal surface on the incide of the oras 21 to argue the term extractly with a substantially constant force proportional to the critical bushing load of the spring almost. Subsequently, the expending tool is passed through the lines to expend it in the century in the secons described by another force.

The foregoing description of a preferred embeliant of my invention has been given for the purpose of examplification. It will be understood that various medifications in the details of accordances will become apparent to

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